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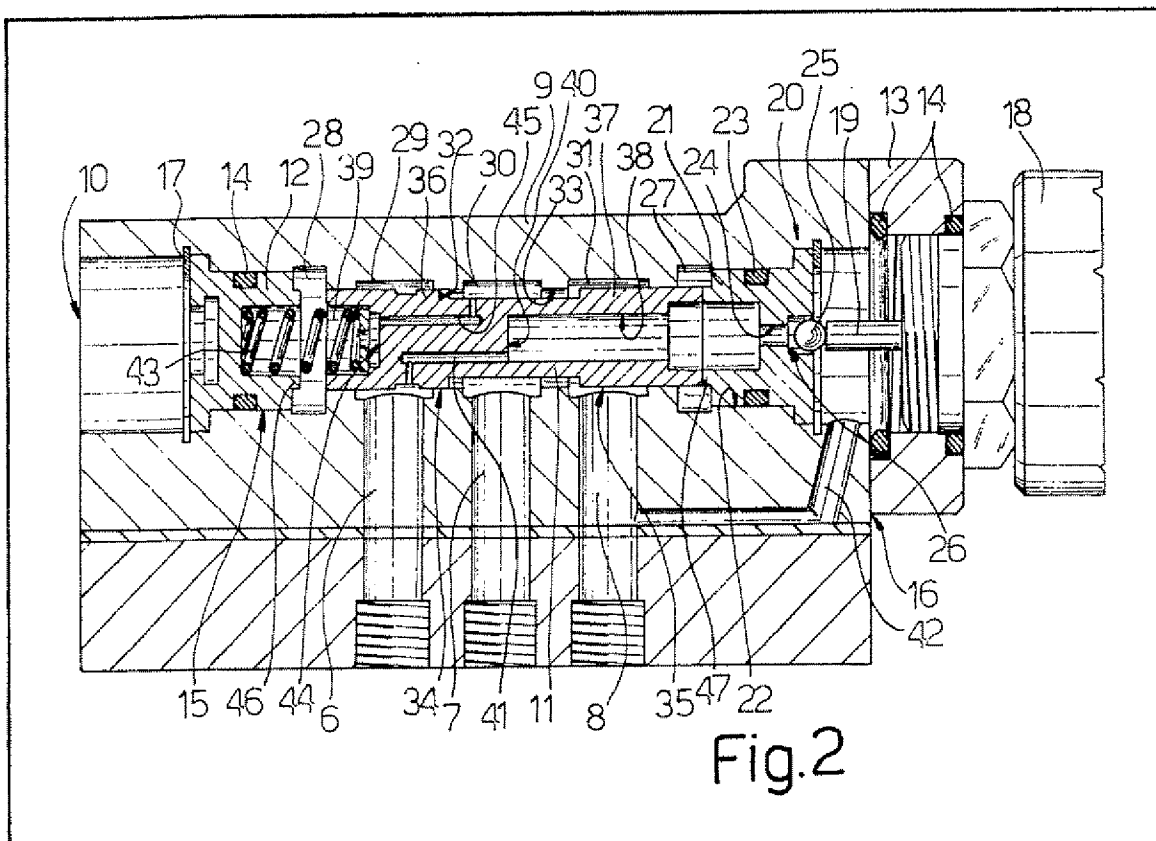
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(54) A solenoid operated pressure control valve

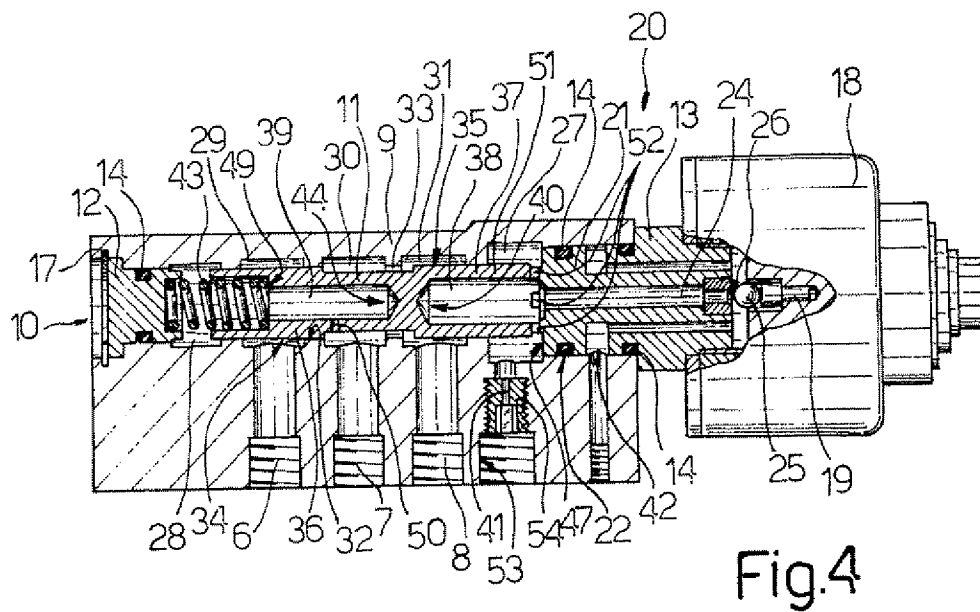
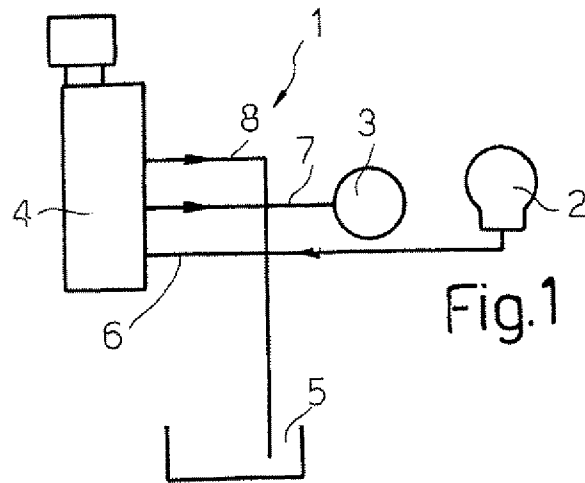
(57) A solenoid operated valve which can be connected in a hydraulic circuit between a utiliser and a source of fluid under pressure for controlling the supply to the said utiliser (3), includes a spool (11) which is movable against the action of resilient means (43) and is provided with a first active surface (40) sensitive to the

pressure in a control chamber (27) provided with an inlet (41) and an outlet (24) for a control fluid. The outlet (24) from the control chamber (27) is provided with an electrically controlled valve member (20) and the spool (11) has a second active surface (44) opposite the first (40) and sensitive to the pressure in a reaction chamber (28) connected (via a passage (145)) to a first duct (7) communicating with the utiliser. The spool (11) is operable to put the first duct (7) in communication with a second duct (8) or a third duct (6) respectively connected to a discharge reservoir and to the said source.

The utiliser may be a clutch of an automatic gearbox.



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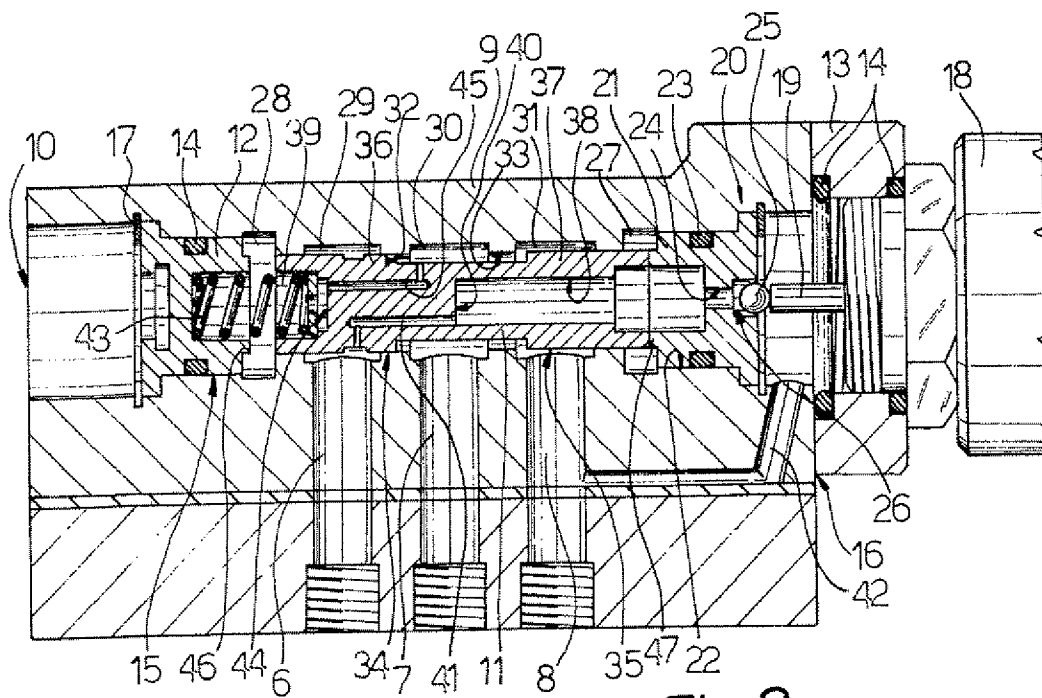


Fig. 2

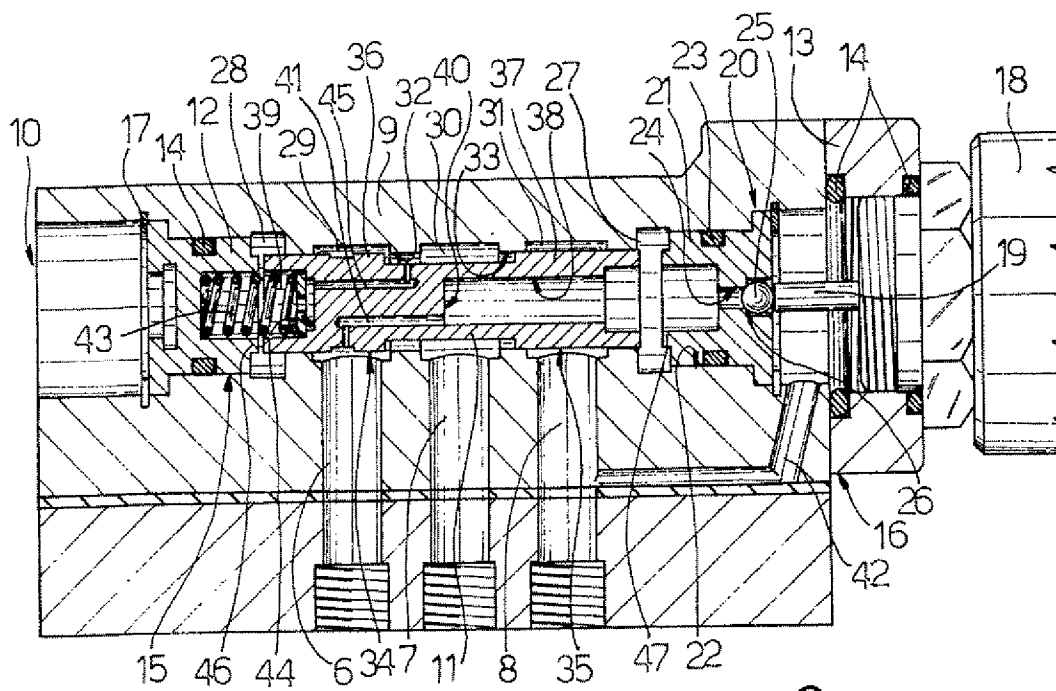


Fig. 3

## SPECIFICATION

**A solenoid operated pressure control valve**

The present invention relates to a pressure control valve which can be connected in an hydraulic circuit between a source of fluid under pressure, a utiliser and a discharge reservoir. Particularly, but not exclusively, the present invention relates to a pressure control valve which can be connected in an hydraulic circuit of an apparatus for control of a continuous automatic gear box such as that described in the Patent application by the Applicant filed on the same date (Italian application of 17th July 1981).

In the said Patent application the engagement and disengagement of the clutches of the automatic gearbox are controlled by means of the delivery or removal of oil under pressure to or from the clutches. To allow a smooth engagement (and disengagement) the pressure and the rate of flow of fluid supplied must be regulated by suitable valves.

The object of the present invention is to provide a pressure control valve which can be connected in an hydraulic circuit between a source of fluid under pressure and a utiliser, to regulate the flow of fluid under pressure towards the utiliser in dependence on an external electrical signal, for example one sent from a central control system. A further object of the present invention is that of providing a supply delay valve which can selectively put the said utiliser in communication with the discharge reservoir.

According to the present invention there is provided a pressure control valve which can be connected in an hydraulic circuit between a source of fluid under pressure and a utiliser, for selectively putting this latter in communication with the said source of fluid under pressure or with a reservoir for discharge of the said fluid, including a control chamber having an input and an output for a control fluid, the said output being provided with an electrically controlled valve member, and a spool provided with a first active surface sensitive to the pressure in the said control chamber, the said spool being movable against the action of resilient means between a first position in which the said spool can put a first duct connected to the said utiliser in communication with a second duct which is connected to the said reservoir, and a plurality of positions in which the said spool puts the said first duct in communication with a third duct connected to the said source, characterised by the fact that it includes a reaction chamber connected by means of a communication passage to the said first duct and provided with a second active surface opposite the said first active surface and movable rigidly with the said spool, the said second active surface being sensitive to the pressure of the said fluid in the said reaction chamber, the volume of this latter varying with the displacement of the said spool.

For a better understanding of the present invention there is now given a non limitative

description of two embodiments thereof with reference to the attached drawings, in which:

Figure 1 schematically illustrates a simplified hydraulic circuit in which there is connected a valve formed according to the principles of the present invention;

Figures 2 and 3 illustrate a longitudinal section of the valve of Figure 1 in two different operating positions; and

Figure 4 illustrates a variant of the valve of Figures 1 and 3.

With reference to Figure 1, an hydraulic circuit is generally indicated with the reference numeral 1, this comprising a source 2 of fluid under pressure, a closed utiliser 3 for example a disc clutch, a pressure regulation valve connected between the source 2 and the utiliser 3, and a discharge reservoir 5 which is open to the atmospheric pressure. A pipe 6 connects the source 2 to the valve 4, whilst this latter is connected to the utiliser 3 and to the reservoir 5 by pipes 7 and 8 respectively.

With reference to Figures 2 and 3, the valve 4 includes a support body 9 in which there is formed a cavity 10 within which a substantially cylindrical spool 11 is slidable. At its opposite ends the cavity 10 is closed by respective plugs 12 and 13 provided with sealing rings 14 and fixed in respective seats 15 and 16 of the body 9 in any convenient manner. In the embodiment illustrated the plug 12 is fixed in position by means of a circlip 17.

The plug 13 is hollow and carries an electromagnet 18 of known type screwed into it, which electromagnet receives control signals from an electronic control system not illustrated and in dependence on these causes axial displacement of a rod 19 in a proportional manner. The rod 19 acts on a valve member 20 housed in the body 9 and comprising a bush 21 fitted in a suitable seat 22 formed in the cavity 10 and provided with a seal 23 and a calibrated hole 24. The hole 24 can be progressively obstructed by a floating ball 25 which is housed in a seat 26 of the bush 21 and is thrust towards the hole 24 by the rod 19.

The cavity 10 is sub-divided into a plurality of adjacent chambers in which the spool 11 can move. In particular, the cavity 10 includes a control chamber 27 adjacent the bush 21, a reaction chamber 28 adjacent the plug 12 and three terminal chambers 29, 30 and 31 respectively, into which open ducts 6, 7 and 8 respectively, these numbers corresponding to the reference numbers of the pipes in Figure 1. The chambers 29, 30 and 31 are disposed in series and communicate with one another through respective ports 32 and 33. The spool 11 slidably engages in the ports 32 and 33 and has respective cylindrical lateral surfaces 34 and 35 formed on lands 36 and 37 of the spool 11 and which can close respective ports 32 and 33 with a fluid tight seal when these ports are engaged by the lands 36 and 37.

The spool 11 has two end cavities 38 and 39

respectively facing into the chambers 27 and 28 of which they constitute enlargements. The cavity 38 has an active surface 40 sensitive to the pressure within the chamber 27. The chamber 27 is in fact constantly maintained full of control fluid which enters into the chamber 27 through an inlet constituted by a calibrated hole 41 formed in the spool 11 and communicating with the duct 6. The chamber 27 is further provided with an outlet for the control fluid, constituted by the hole 24 the flow cross section of which is determined by the position of the floating ball 25 which is positioned by the magnet 18 via the rod 19. The control liquid which passes through the hole 24 collects in a chamber lying between the bush 21 and the plug 13 from which it flows out into the duct 8 through an outlet passage 42.

The cavity 39 houses a helical spring 43 positioned between the spool 11 and the plug 12 and against the action of which the spool 11 can move. The cavity 39 is further provided with an active surface 44, opposite the surface 40, and sensitive to the pressure in the reaction chamber 28.

The reaction chamber 28 is, in each position of the spool 11, connected to the cavity 30 and the associated duct 7 by means of a communication passage 45 formed within the spool 11. It is therefore filled with fluid under pressure supplied to the utiliser 3. The chambers 27 and 28 are finally provided with respective end-of-stroke abutments 46 and 47 for the spool 11, formed on the plug 12 and the bush 21 respectively.

In Figure 4 there is illustrated a variant of the valve of Figures 2 and 3 in which the same or similar parts are indicated with the same reference numerals. The valve 4 of Figure 4 is very similar to that of Figures 2 and 3 and differs from this by the different form of the spool 11. In particular, the spool 11 is provided with substantially cylindrical cavities 38 and 39 of dimensions which are greater than those of the corresponding cavities in the valve 4 of Figures 2 and 3. The cavity 39 has an abutment 49 for the spring 43 and communicates with the duct 7 through a connection passage constituted by a radial hole 50 formed in the spool 11. This latter has an end 51 facing a shoulder 47 provided with notches 52 through which the control fluid can pass from the chamber 27 to the chamber 38 and thus exert a pressure on the active surface 40. The control fluid enters into the chamber 27 through an inlet passage 53 provided with a bush 54 having a calibrated hole 41. The control fluid can flow out from the chamber 27 through the hole 24 the flow cross section of which is determined by the position of the ball 25, and then discharged through the outlet passage 42 which is formed in part in the body 9 and in part in the plug 13.

With reference to Figures 1, 2 and 3, the operation of the valve 4 is as follows.

When it is not desired to supply fluid under pressure to the utiliser 3 the electromagnet 18

is not supplied with any signal. In this way the rod 19 is not forced against the ball 25 and therefore this latter is free to move in the seat 26 without throttling the hole 24. Therefore the control fluid which enters the chamber 27 is free to flow out without difficulty.

In these conditions the spool 11 is located in the position of Figure 2 in which the surface 24 closes the port 32, whilst the port 33 is open in that it is not engaged by the land 37. In fact, in the chamber 27 there is a very low pressure in that the control fluid under pressure bleeds through the calibrated hole 41 experiencing a strong pressure drop. For this reason the thrust exerted on the spool 11 by the spring 43 is greater than that exerted by the control fluid on the active surface 40 and therefore the spool 11 is thrust against the shoulder 47. In the position of Figure 2 the spool 11 therefore allows the duct 7 to communicate with the duct 8 through the port 33, and thus the valve 4 connects the utiliser 3 with the discharge reservoir 5. When on the other hand it is desired to supply fluid under pressure to the utiliser 3 a predetermined electrical signal is supplied to the electromagnet 18 which causes the rod 19 to become displaced to a predetermined position throttling the hole 24 with the ball 25. Because of the reduction in the flow cross section of the hole 24 the pressure of the control fluid in the chamber 27 rises since the control fluid partially accumulates in it. Consequent on this pressure increase the thrust exerted by the control fluid on the spool 11 first equals and then exceeds the thrust of the spring 43 and therefore the spool 11 begins to move towards the plug 12 compressing the spring 43 to reach a new equilibrium position. Depending on the pressure of the fluid in the chamber 27 the spool 11 can move to a plurality of general positions, one of which is illustrated in Figure 3. In this position the port 33 is closed by the surface 35 whilst the port 32 is open and puts the ducts 6 and 7 in communication with one another. Thus the utiliser 3 communicates with the source 2 and is isolated from the exhaust 5. During the change between the opening of the hole 32 and the stopping of the spool 11 in the new equilibrium position the pressure in the duct 7 increases progressively until it becomes equal with the pressure in the duct 6 in that the fluid is bled through the hole 32 and therefore accumulates in the utiliser 3. The pressure in the duct 7 increases very slowly because the movement of the spool 11 is not opposed only by the spring 43 but also by the thrust exerted by the fluid in the duct 7 on the active surface 44. In fact, the fluid under pressure, through the duct 45, fills the reaction chamber 28 exerting on the spool 11 a contrary thrust which delays the movement. The equation of equilibrium of the spool 11 is:

$$P.A=P1.A1+K X \quad (1)$$

where P and P1 are, respectively the pressure of the fluid in the chamber 27 and the pressure of

the fluid in the chamber 28, A and A1 are the areas of the surfaces 40 and 44 respectively (preferably  $A=A1$ ), K is the elastic constant of the spring 43 and X is the displacement of the spool 11 against the spring 43.

Therefore the movement of the spool 22 is opposed by the term  $(P1.A1)$  which progressively slows the spool 11.

At the end of the movement the contrary thrust exerted by the fluid in the chamber 28 and the spring 43 exceeds the thrust of the control fluid and therefore the spool 11 reverses its direction of movement. The increase in the volume of the chamber 28 consequent on the displacement of the spool 11 towards the plug 13 makes the pressure in the fluid contained in the chamber 28 fall and therefore the spool 11 stops as soon as the thrusts on it are in equilibrium. A beneficial stabilising effect is thus obtained which does not permit the reopening of the communication with the duct 8 which would trigger dangerous oscillations of the spool 11.

By sending a different signal to the magnet 18 a different pressure in the control chamber 27 is obtained and it is thus possible, for example, to reopen the port 33 and regulate the progressive discharge of the utiliser 2. It is also possible to vary the operation time of the valve 4 (spool transmit duration).

### 30 Claims

1. A pressure control valve (4) which can be connected in an hydraulic circuit (1) between a source (2) of fluid under pressure and utiliser (3) for selectively putting this latter in communication with the said source (2) of fluid under pressure or with a discharge reservoir (5) for the said fluid including a control chamber (27) having an inlet (41, 53) and an outlet (24) for control fluid, the said outlet (24) being provided with an electrically controlled valve member (20) and a spool (11) provided with a first surface (40) sensitive to the pressure existing in the control chamber (27), the said spool (11) being movable against the action of resilient means (43) between a first position in which the said spool (11) can put a first duct (7) connected to the said utiliser (3) in communication with a second duct (8) communicating with the said reservoir (5) and a plurality of positions in which the said spool (11) can put the said first duct (7) in communication with a third duct (6) connected to the said source (2) characterised by the fact that it includes a reaction chamber (28) connected by means of a communication passage (45, 50) to the said first duct (7), provided with a second active surface (44) opposite to the said first active surface (40)

and movable together with the spool (11), the said second active surface (44) being sensitive to the pressure of the said fluid in the said reaction chamber (28) the volume of this latter varying with the displacement of the said spool (11).

2. A valve (4) according to Claim 1, characterised by the fact that the said spool (11) is substantially cylindrical and slides within a cavity (10) formed in the support body (9) in which the said first (7), second (8) and third (6) ducts terminate, and including the said control (27) and reaction (28) chambers.

3. A valve (4) according to Claim 2, characterised by the fact that the said control chamber (27) and reaction chamber (28) are disposed at the opposite ends of the said cavity (10), this latter further including three terminal chambers (30, 31, 29) respectively communicating with the said first (7), second (8) and third (6) ducts and connected in series by means of a first port (32) and a second port (33) respectively.

4. A valve (4) according Claim 3, characterised by the fact that the said spool (11) slidably engages the said first and second ports (32, 33) and is provided with respective lateral surfaces (34, 35) operable to close the said first and second ports (32, 33).

5. A valve (4) according to any preceding Claim, characterised by the fact that the said communication passage (45, 50) is formed within the said spool.

6. A valve (4) according to any preceding Claim, characterised by the fact that the said inlet (53) of the said control chamber (27) is provided with a bush (54) having a calibrated restriction (41).

7. A valve (4) according to any of Claims 1 to 5, characterised by the fact that the said inlet into the said control chamber (27) is constituted by a calibrated hole (41) formed in the said spool (11) and communicating with the said third duct (6).

8. A valve (4) according to any preceding Claim, characterised by the fact that the said second active surface (44) is formed on the said spool (11) in correspondence with a cavity (39) at the end of this latter, facing the said reaction chamber (28) and housing the said resilient means (43).

9. A valve (4) according to any preceding Claim, characterised by the fact that the said control chamber (27) and reduction chamber (28) are provided with end-of-stroke abutments (46, 47) for the said spool (11).

10. A supply valve (4) with delay substantially as described with reference to the attached drawings.